

FINAL REPORT OECD CRP FELLOWSHIP

PROF ANTHONY R. CLARKE

School of Biology and Environmental Science, Queensland University of Technology, Brisbane,
Queensland 4001, Australia

Fellowship title	Researchers know it, but do regulators? Lesser-known aspects of fruit fly invasions
Theme number of research fellowship	Theme 2: Managing risks in a connected world
Host Institution	Universität für Bodenkultur Wien (BOKU Wien) [= University of Natural Resources and Life Sciences, Vienna]
Name of host collaborator	Prof Dr Christian Stauffer
Dates of fellowship	1 st August 2022 to 5 th November 2022 (Fellowship awarded in 2019 for commencement in 2020, delayed due to Covid-19)
Consent to post report	I provide consent for this report to be posted on the OECD website.

1. What were the objectives of the research project? Why is the research project important?

Tephritid fruit flies (Diptera: Tephritidae) are internationally significant pests of horticulture, attacking most fleshy fruits and vegetables. Adults lay their eggs into sound fruit on-plant, where the subsequent larvae feed and grow. Larval feeding causes direct crop loss. Additionally, because recently infested fruit appears sound, fruit flies pose significant problems as quarantine pests because infested fruit can be spread through commercial and non-commercial carriage. Despite quarantine, fruit fly incursions happen across the globe with alarming frequency and successful invasions are frequent. In the last two decades the introduction of *Bactrocera dorsalis* into sub-Saharan Africa is the highest profile and damaging fruit fly invasion, but this is only one of several examples. Because of their impact, significant regulatory effort is put into preparing pest risk analyses (PRAs) to anticipate the likelihood of fruit fly invasion and to plan responses if one occurs. Unfortunately, published PRAs miss two major issues which impact on fruit fly invasions: (i) that tropical fruit flies have complex seasonal phenologies that may be aiding their ability to survive in climatically unfavourable areas; and (ii) that the incursion of a new fruit fly species invariably negatively impacts on existing fruit flies. Both of these issues have significant biosecurity implications.

The objectives of the fellowship were to review and promote (via personal contacts, workshop presentation and publication) these two topics, so raising their profile with regulatory and policy agencies. Better knowledge of these areas will not stop fruit fly incursions, but they will help countries better understand and manage the risk posed by invasive fruit flies. As such, the project directly addressed CRP Theme 2: Managing risks in a connected world.

2. Were the objectives of the fellowship achieved?

The two-year delay in taking up the fellowship due to the global Covid-19 pandemic allowed time to work on the fellowship objectives well before taking up the fellowship. This meant that the full objectives of the fellowship could be met and finalised during the fellowship period.

The original goals were to carry out literature reviews in two areas, with ideally one review submitted to a journal for publication during the fellowship period and a second manuscript completed and submitted in the year following the fellowship. Additionally, the topics were to be presented at a European regional meeting and to government regulators where possible. At the time of writing this report both manuscripts have been published and information from the reviews has been communicated to different regulatory groups.

The importance of competition in fruit fly invasions was reviewed and partially written in an internal report format prior to the commencement of the fellowship. That report was requested by, and then confidentially distributed to, Australia's National Plant Protection Office (NPPO) in the first half of 2022 to inform domestic policy decisions which were of urgency at the time. The Australian Commonwealth Government was aware that the report would be expanded and ultimately published in a publicly accessible location. During the fellowship period that report was broadened to increase its international relevance and is now published (see next section).

The second review area was around the topic of why climate matching models appear to be failing for tropical fruit flies. Importantly for risk analysis, flies are establishing in cold temperate areas where models predict they should not be able to establish. Between 2019 and the middle of 2022 a research initiative I led carried out a large amount of primary research in the general area of fruit fly seasonality and adaptability. Through that project I needed to read widely on mechanisms of insect diapause and seasonality, and particularly on how tropical insects (such as fruit flies) utilise diapause and quiescence to escape seasonally unfavourable periods. With this background, when I arrived in Vienna with time to think and write I was able to rapidly synthesise my thoughts into a full review manuscript which is

now published (following an extraordinarily quick review and handling period) in a peer reviewed journal (see next section). The main findings of this second review were presented and discussed in Athens in mid-October as part of a workshop held by the EU H2020 funded project *FF-IPM: In-silico boosted, pest prevention and off-season focused IPM against new and emerging fruit flies* led by Prof Nikos Papadopoulos, Uni of Thessaly; and in a publicly advertised seminar delivered at the host-institution BOKU on the 13th September.

3. What were the major achievements of the fellowship?

The major achievements of the fellowship are two review/synthesis manuscripts on different aspects of fruit fly biology pertinent to understanding and managing the risk posed by fruit flies as invasive organisms. Clarke and Measham (2022) is explicitly written for plant-health regulators and managers; while Clarke et al. (2022) is primarily written for scientists but with the risk management and invasion implications of the work explicitly articulated. Both papers acknowledge the support of the OECD and both have been published in open-access format.

Clarke A.R. & Measham P.F. 2022. Competition: a missing component of fruit fly (Diptera: Tephritidae) risk assessment and planning. *Insects* **13**: 1065. <https://doi.org/10.3390/insects13111065>

Clarke A.R., Leach P. & Measham P.F. 2022. The fallacy of year-round breeding in polyphagous tropical fruit flies (Diptera: Tephritidae): evidence for a reproductive diapause in *Bactrocera* species. *Insects* **13**: 882. <https://doi.org/10.3390/insects13100882>

4. Will there be any follow-up work?

Follow-up research directly related to the fellowship is not anticipated as it has been fully completed and made available in the public domain. It is hoped research collaboration on invasive fruit flies may continue, but this will be dependent on new funding being won. Had the fellowship been able to be taken in 2020 when initially planned then follow-up work would almost certainly have occurred because of research funding then held, but that funding is now finished and new funding is being sought.

More broadly, it is hoped that that the links between home (QUT, Brisbane) and host (BOKU, Vienna) institutions will grow and strengthen because of this fellowship. The two organisations previously had a formal collaborative agreement for staff and student exchange, but this lapsed because of poor engagement, particularly from the QUT end. With Clarke now having a much better idea of the academic and physical environment offered by BOKU, I hope to reinvigorate the collaboration by encouraging academic colleagues and postgraduate students to see BOKU as an exciting and valuable destination for collaboration and exchange.

5. How might the results of your research project be important for helping develop regional, national or international agro-food, fisheries or forestry policies and, or practices, or be beneficial for society?

Fruit flies are highly invasive organisms, being moved around the world through commercial and non-commercial fruit movement. The impacts of a fruit fly invasion can be devastating for commercial horticultural production, as well as causing massive changes to traditional, non-commercial horticultural production (i.e. 'back-yard' and allotment production). As an example, when areas of Australia which had been previously free of fruit fly were invaded by the fruit fly *Bactrocera tryoni*, international trade was halted for several major industries (e.g. citrus), while back-yard growers had trees compulsorily removed to try and manage the pest. To stop or reduce such losses, pest risk analysis and emergency planning for fruit fly invasion is carried out routinely by countries and regions (e.g. the European Union) around the world.

The outcomes of the fellowship will help inform and improve these planning activities. The review of fruit fly competition identifies six different mechanisms by which competition between existing and

invasive fruit flies will modify the biological and economic impacts of a fruit fly invasion and illustrates each with scenarios. Specific direction is provided on the need for incorporating competition into PRA's and where further research is warranted. The review of phenology of *Bactrocera* fruit fly species identifies the high likelihood of a complex reproductive physiology in these insects which allows them to survive for many months without breeding. Should this be confirmed then the population modelling of *Bactrocera* populations will be greatly improved for use in the timing of pest management controls. Further, reproductive diapause makes insects more tolerant of cold stress. If it is confirmed that *Bactrocera* species do diapause then it greatly extends their capacity to survive in cold temperate areas, increasing the risk they pose to regions such as Europe and North America. Incorporation of this information into PRAs will improve their predictive capacity and so improve risk planning and response strategies against fruit flies.

6. How was this research relevant to the objectives of the CRP and the CRP research theme?

The fellowship addressed the broad objectives of the CRP by facilitating international cooperation and leading to improved scientific knowledge. Additionally, as fruit flies are major horticultural pests then their better management increases food security, particularly in developing nations. More explicitly, at the theme level, the research helps to manage risk in a connected world. Fruit flies are highly invasive, being moved as eggs and larvae in infested fruit. Whether commercial horticultural trade or airline passengers carrying fruit for personal consumption is the greater risk is an ongoing debate within the fruit fly community, but in reality the point is mute as the real risk is that we live in a connected world where fruit can be physically transported from one side to the other in 24 hours. This poses great risk to agriculture through the movement of plant pests. By reviewing two key areas of the biology of fruit flies, specifically within a context of how that biology impacts on fruit flies as invasive pests, helps to decrease the risk posed by these insects through better preparedness and response planning.

7. Satisfaction

The fellowship was delayed for a full two years through the impacts of the Covid-19 pandemic. During this period the OECD were incredibly supportive in continuing to honour the fellowship and allowing it to proceed. BOKU and my host Prof Christian Stauffer were similarly welcoming regardless of the delays. The ability to spend uninterrupted thinking and writing time in the city of Vienna, while bouncing ideas with Christian, has made the fellowship highly enjoyable and rewarding. However, it is important to note that the fellowship would have achieved different goals if carried out in 2020 as was initially planned. Had it been carried out in 2020 then the writing would not have been so advanced, but there would have been a much greater probability of further, post-fellowship collaboration as I then had funding that could have supported the exchange of a postgraduate research student and a postdoctoral research fellow. With the fellowship delayed until 2022 much more background work was done in Australia before arrival, meaning that two full manuscripts were able to be achieved in only 14 weeks. However, with the previously existing grant now finished, follow-up activities will be dependent on new funding being sourced.

Covid aside, the fellowship was highly rewarding and no practical problems were encountered. As a tenured professor already the fellowship will not directly increase my career opportunities. But by making myself place fundamental biology within the context of policy and regulatory action, the fellowship has increased my breadth of skills and I hope to carry out more such activities in the future with Australia's NPPO.

8. Advertising the Co-operative Research Programme

I first learnt of the CRP fellowship while doing intensive web searches for schemes which would fund academic sabbatical. I then followed up with discussions with Dr Gary Fitt, an Australian colleague who had been closely linked with the scheme. After Gary retired he was replaced by Dr Max Suckling as the regional representative. Both Gary and Max encouraged me to apply for the scheme and gave

advice on the 'slant' to take when writing an application. While I found the scheme through searching, I have noted that it is not widely known among my peers. I suspect this is because agricultural scientists do not automatically think of the OECD as an organisation that will fund agriculture related activities. I'm not sure how to make it more visible, but I do believe that it should be made more visible.

I have no other issues to record, other than to acknowledge the simultaneously professional and friendly support of Ms Nathalie Léglise at all stages of the fellowship. I thank the OECD CRP for its support.